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The summation of sound signals from simultaneous commentaries

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Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

RESEARCH DEPARTMENT

THE SUMMATION OF SOUND SIGNALS FROM SIMULTANEOUS COMMENTARIES

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(EL-38)

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Section	Title	Page
	SUMMARY	1
1.	INTRODUCTION	1
2.	TEST EQUIPMENT	1
3.	TEST PROCEDURE	1
4.	PROCESSING OF DATA	3
	4.1. Maximum Level of Individual Signals	3
	4.2. Maximum Level of Combined Signals	3
	4.3. Law of Summation	3
5.	RESULTS	4
6.	CONCLUSIONS	4
7.	REFERENCES	4
	APPENDIX I	7

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THE SUMMATION OF SOUND SIGNALS FROM SIMULTANEOUS COMMENTARIES

SUMMARY

The law of summation of sound signals applicable to simultaneous commentaries has been investigated using multitrack recordings made at the Tokyo and Mexico Olympic Games. For the sum of 10 channels the level exceeded for 1% of the time is up to 8½ dB above the corresponding figure for a single channel.

1. INTRODUCTION

In a multiplex transmission system in which the instantaneous magnitudes of the signals in the individual channels are additive, the total power to be transmitted depends on the statistical distribution of the individual signal levels and on any correlation which may exist between these signals. If the transmission system is to be used efficiently, but without unacceptably high probability of overloading, the relationship between the maximum level in the individual channels and the maximum level in the multiplex link must be known.

For telephonic conversation, where there is no correlation between signals in the various channels, the necessary relationship has been derived by Holbrook and Dixon.[1] No corresponding data is however available for simultaneous broadcast commentaries, where an element of correlation may be introduced by the action in the event being described. An analysis of the summation of signals of the latter type has therefore been carried out using recordings, provided by the EBU, of multilingual commentaries on events in the Olympic Games in Tokyo 1964 and in Mexico 1968. The multitrack machine used to reproduce the recordings was also lent by the EBU.

Time did not permit more than a small fraction of the available material to be analysed and a selection of passages to be investigated was made by listening. Ten items, listed in Appendix I, were chosen as representative. The first eight consisted of commentaries on sporting events having moments of climax in the action being described; in these, periods of high-level speech tended to coincide on the various channels and a measure of correlation is thus introduced. The other two items, excerpts from commentaries immediately following and immediately preceding sporting events, were included for comparison; in these items the commentaries were of an excited nature, though there were no common factors which might be expected to introduce an element of correlation in the fluctuation of the levels of individual channels.

No effects attributable to syllabic compression were heard on any of the recorded material, but the speech quality of some commentaries suggests that on occasions instantaneous clipping may have been applied to the signal waveform.

2. TEST EQUIPMENT

The apparatus used for the statistical analysis[2] consists essentially of a full-wave quasi-peak rectifier circuit driving a number of counters set to operate at prescribed input levels spaced at 2 dB intervals, and thus to record the percentage of time for which these levels are exceeded. The charge time constant of the rectifier circuit was made 2½ ms, giving an integration time equal to that of the BBC type ME12/4 peak programme meter. To give the greatest possible resolution of detail, sampling was carried out 20 times per second, the highest rate at which the counters would operate reliably, while the discharge time constant of the rectifier circuit was reduced, from the nominal 1 second in the ME12/4 programme meter, to 200 ms.

The various channel outputs from the multitrack tape recorder were combined as required in a resistive network which included a 1 dB step attenuator in each channel and a 0·1 dB step attenuator in the combined output to allow necessary adjustments to be made.

3. TEST PROCEDURE

The object of this work was to establish the maximum signal excursion which must be catered for if several simultaneous sound commentaries are to be covered by a multiplexed system using amplitude-modulated subcarriers.

It was agreed in discussion between the BBC and EBU Engineers that the most satisfactory way of presenting the result would be in terms of the maximum signal level exceeded for 1% of the time. The experimental procedure was, therefore, intended to give this result in the most realistic manner.

In practice, each commentary would be monitored by some kind of level indicator and the gain controlled to a pre-determined occasional peak reading. The experimental procedure uses the same technique; each of the contributary signals was adjusted to a prescribed maximum level,

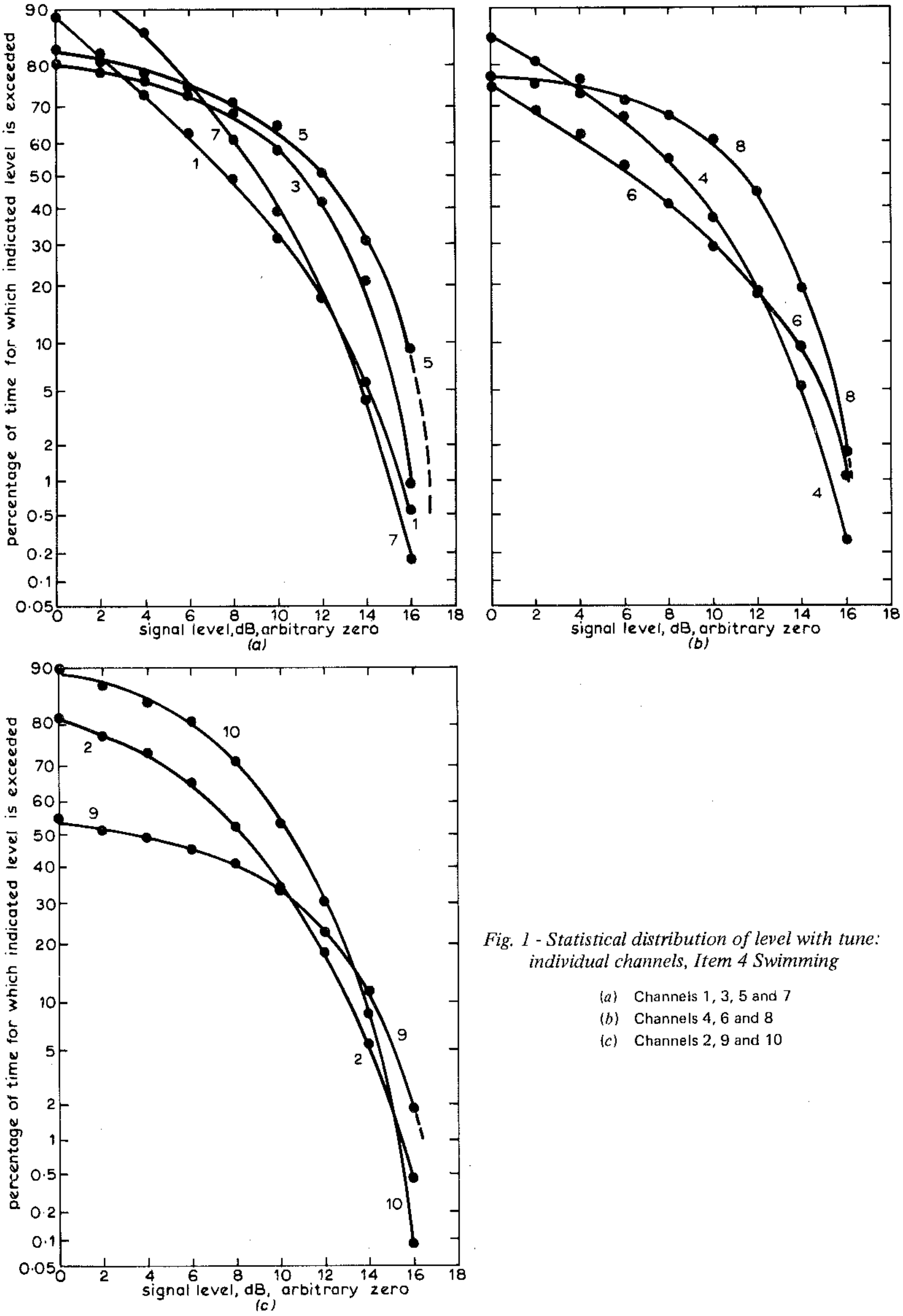

Fig. 1 - Statistical distribution of level with tune: individual channels, Item 4 Swimming

(*a*) Channels 1, 3, 5 and 7
(*b*) Channels 4, 6 and 8
(*c*) Channels 2, 9 and 10

with an estimated accuracy of ±½ dB, using a standard BBC peak programme meter, Type ME12/4. When all the signals had been so adjusted they were applied to the analysing equipment, first individually, and then in combination through a resistive combining network.

It could possibly be argued that a more rigorous way of analysing the summation of signals from simultaneous commentaries would be to adjust each of the contributing signals to a prescribed maximum level which is exceeded for only 1% of the time. This more rigorous approach was rejected on two counts; first, it is not representative of the practical situation and secondly, it would make the experimental procedure extremely long and tedious. In any event, it was shown in the course of the work (see Section 5) that the difference between the two approaches is in practice negligible.

During the analysis of the combined signals, attenuation equal to 10 $\log_{10}$ (number of channels) decibels was included in the common circuit in order to keep the level of the combined signals within the range of the level analysis equipment.

Later in this report the term '1% level' is used to denote the maximum signal level which is exceeded for only 1% of the time.

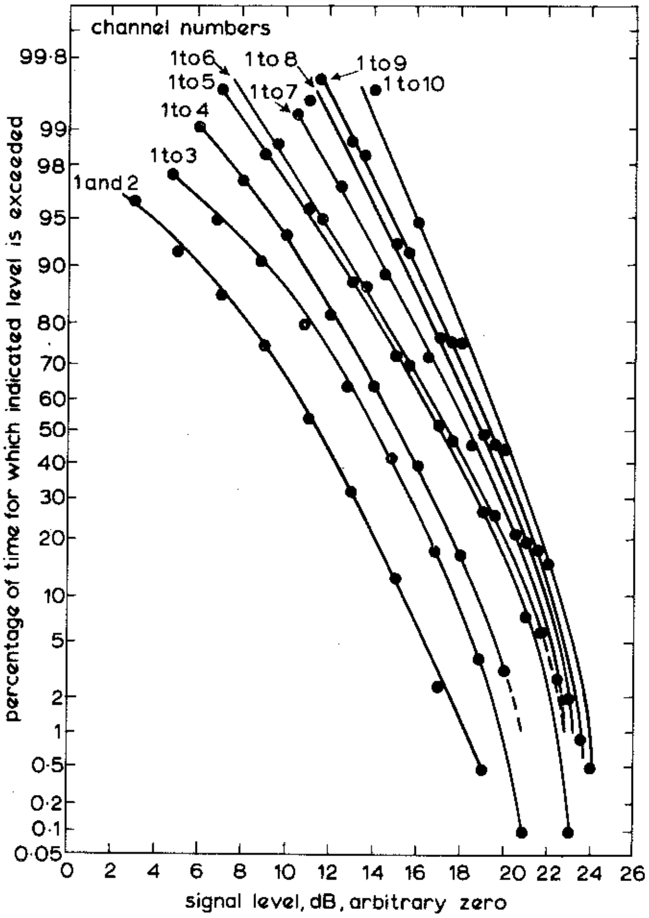

Fig. 2 - Statistical distribution of level with tune: combined signals, Item 4 Swimming

4. PROCESSING OF DATA

4.1. Maximum Level of Individual Signals

The single level representing the maximum for an individual channel was derived from the data for the individual channels by an averaging process.

Initially, a single cumulative probability curve was obtained by averaging the percentage times for which given levels were exceeded in the individual channels concerned and a figure representing the maximum level for one channel was then read from this curve. (It may be noted that the same probability curve would have been obtained if all the commentaries concerned had been presented consecutively and the signal levels analysed over the whole period.)

Later, the maximum level for one channel was arrived at by the more rigorous process of averaging the 1% levels for the individual channels concerned.* By way of illustration Fig. 1 shows, for Item 4, the cumulative probability curves for all ten channels. From each such curve the 1% level was read (generally by interpolation, occasionally by extrapolation); these figures were then averaged** to obtain a value representing the maximum level for one channel.

All the figures given in this report were derived by the latter, more rigorous method; the former, less rigorous, method was found to yield values of maximum level for a single channel up to ½ dB too high.

The procedure described above was carried out for each grouping of channels – Channel 1 and Channel 2, then Channel 1 and Channel 2 and Channel 3, and so on.

4.2. Maximum Level of Combined Signals

Fig. 2 shows, for Item 4, cumulative probability curves for Channel 1 plus Channel 2, Channel 1 plus Channel 2 plus Channel 3, and so on. Allowance has been made for the attenuation deliberately introduced during the analysis and the intervals between the curves therefore represent real differences in levels. For the present purpose the 1% level was read from each curve.

4.3. Law of Summation

The difference between the maximum level for the sum of the signals of a given group and the maximum level for a single channel – calculated, for the same group, in the manner previously described – was derived for Channel 1 and Channel 2, Channel 1 and Channel 2 and Channel 3, and so on. The results for the various items, plotted in Figs. 3 to 7, against the number of channels concerned, indicate the law of progressive addition.

* At the suggestion of Dr. R.D.A. Maurice.

** Signals equated by observation of a peak programme meter were found to have a spread of no more than ±1¾ dB in the levels exceeded for 1% of the time. The arithmetic and geometric means of the 1% levels are therefore substantially equal and the simpler procedure of averaging the signal levels, expressed in decibels, was adopted.

5. RESULTS

For Items 1 to 8, which consist of commentaries on events having periods of climax, the differences between the '1% level' for 10 channels and the corresponding level for the average single channel lie in the range 5½ dB to 8½ dB. Items 9 and 10, commentaries on events having no well-defined climax, gave differences of about 7 dB and 5 dB respectively.

For large numbers of channels the level distribution of the combined signals may be expected to approach the Gaussian form. In these circumstances the signal level exceeded for a particular percentage of time would rise by 3 dB for every doubling of the number of channels; this rate of increase is apparently reached in Items 7 and 8 and it may be assumed that in every case the curves would ultimately rise at this rate. An estimate of the level for more than the available number of channels may be made from the extrapolation of the curves of Figs. 3 to 7. Some uncertainty necessarily arises in this operation and, to give further guidance, the line representing the maximum possible rate of increase of level is included in each case.

In the case of Item 4, the analysis was repeated using the process, mentioned in Section 3, of equating the 1% levels of the individual channels before analysing the sum signals. The results are shown in Fig. 4(*b*), together with those obtained by the less rigorous process; it will be seen that the two sets of data are in good agreement.

The selection for analysis, of the combinations 'Channel 1 plus Channel 2' and so on, was arbitrary. For one item, the relationship between the 1% level and the number of channels was redetermined for two other groupings. The resulting three curves diverged slightly, the spread being ¾ dB for 10 channels.

6. CONCLUSIONS

The law of summation of signals from simultaneous commentaries on the same event depends on the nature of the event being described.

Where the action has moments of climax some element of correlation may be expected in the fluctuation of levels in the individual channels; in cases of this kind the maximum (1% of time) level for the sum of 10 signals was found to be 5½ dB – 8½ dB above the maximum for one signal. In two cases where the event being described had no such common stimulus the corresponding figures were 5 dB and 7 dB respectively.

7. REFERENCES

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2. New equipment for the statistical-analysis of sound programme levels. BBC Research Department Report No. L-070, Serial No. 1966/65.

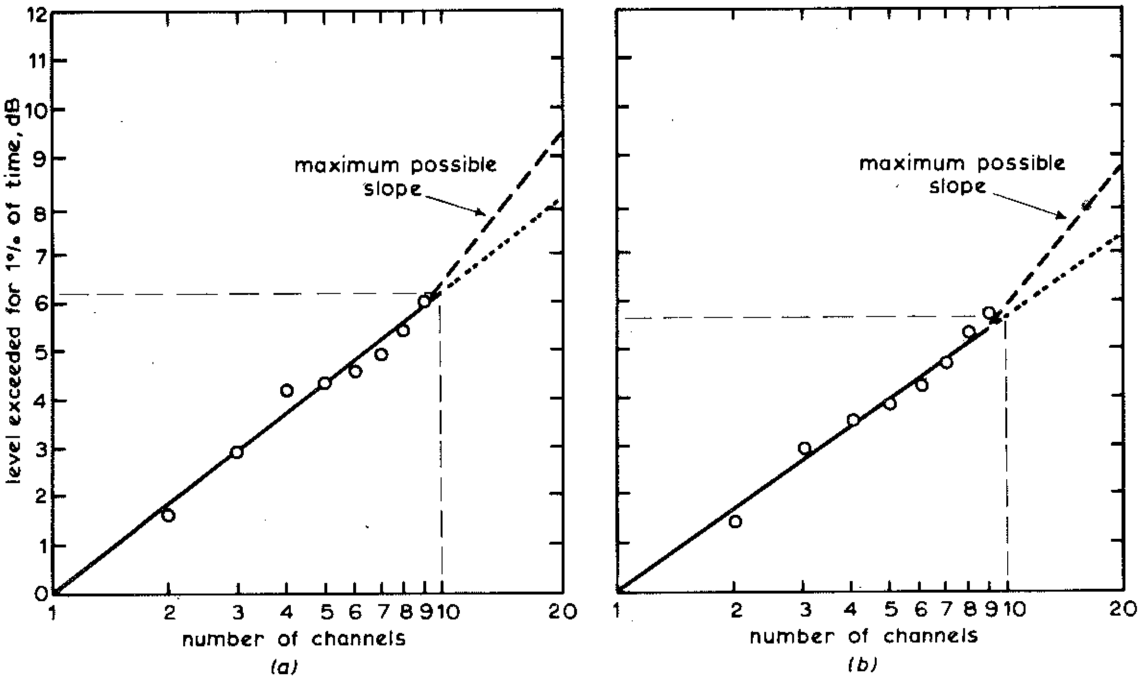

Fig. 3 - Increase in level of combined signal with number of channels
(*a*) Item 1 Athletics (*b*) Item 2 Athletics

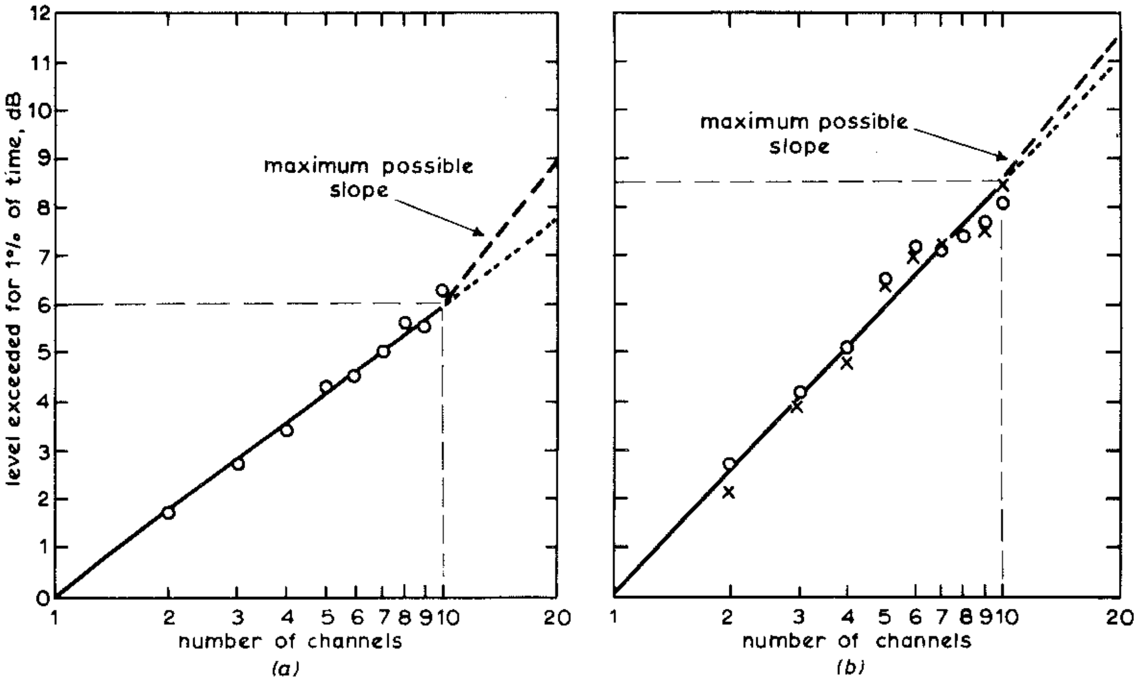

Fig. 4 - Increase in level of combined signal with number of channels

(*a*) Item 3 Athletics

(*b*) Item 4 Swimming

o Individual channel signals equated by peak programme meter

x Individual channels equated at 1% level

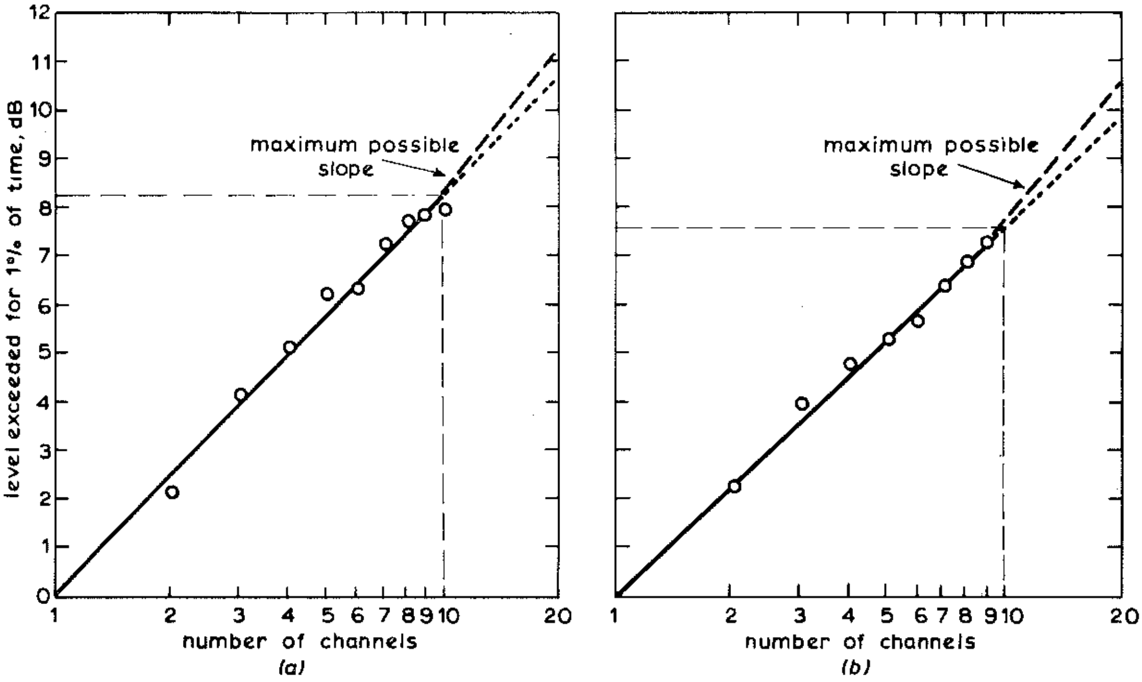

Fig. 5 - Increase in level of combined signal with number of channels

(*a*) Item 5 Swimming (*b*) Item 6 Swimming

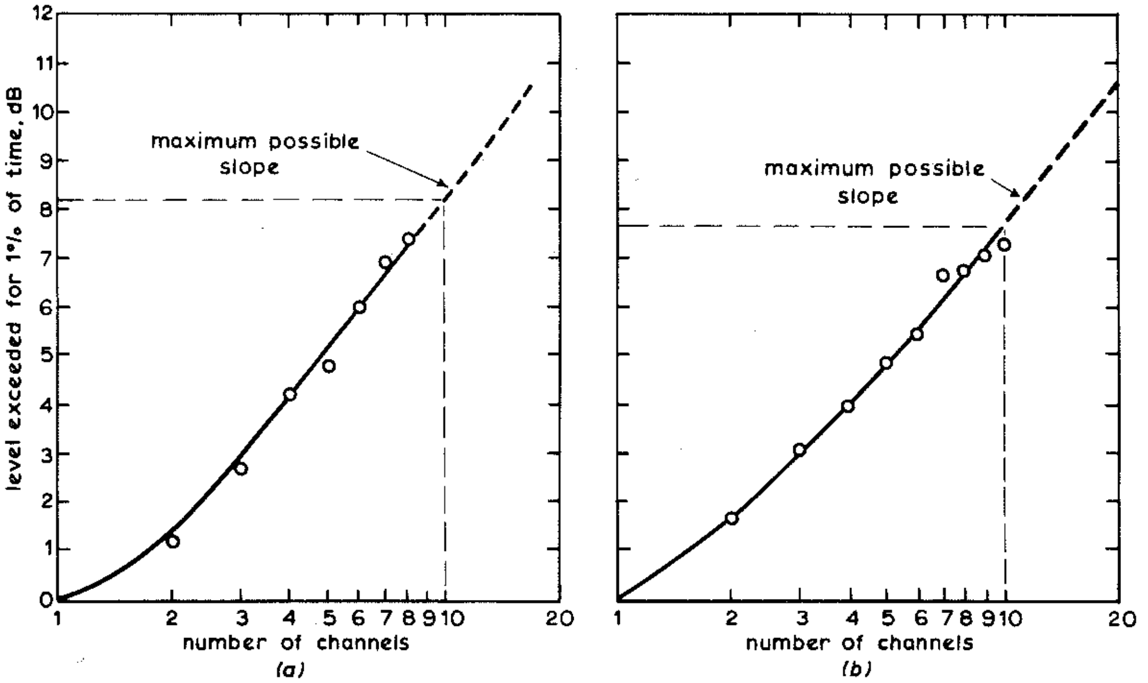

Fig. 6 - Increase in level of combined signal with number of channels

(*a*) Item 7 Equestrian Event (*b*) Item 8 Football

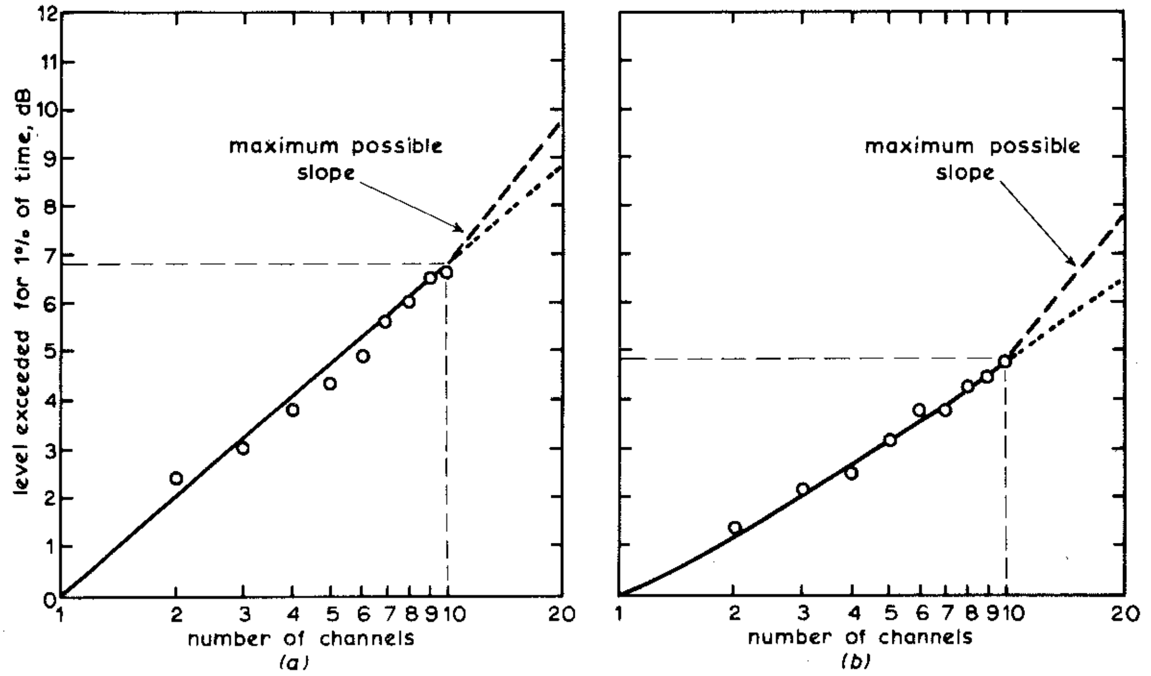

Fig. 7 - Increase in level of combined signal with number of channels

(*a*) Item 9 Football: Commentary following event (*b*) Item 10 Athletics: Commentary preceding event

APPENDIX I

Item	Source	Number of Simultaneous Commentaries	Nature of Event	Duration of excerpt	Identification on recorded cue track (Units of 5 seconds)
1.	Mexico 17.10.68	9	Athletics. 1500 m Third Heat (Last Lap)	1 min 5 sec.	302/315
2.	Mexico 17.10.68	9	Athletics. 1500 m Third Heat (Excluding last lap)	2 min 45 sec.	269/302
3.	Tokyo 17.10.64	10	Athletics. 400 m Final. Ladies	55 sec.	3553/3564
4.	Tokyo 12.10.64	10	Swimming. 100 m Freestyle. Final.	1 min 5 sec.	8255/8266
5.	Tokyo 12.10.64	10	Swimming. 200 m Backstroke semifinal. (Last 50 secs.)	50 sec.	7450/7460
6.	Tokyo 13.10.64	9	Swimming. 100 m Freestyle Final. Ladies	55 sec.	7780/7791
7.	Tokyo 24.10.64	8	Equestrian Event. Part of Second round by eventual winner	1 min 25 sec.	8883/8900
8.	Tokyo 23.10.64	10	Football. Excerpt from commentaries on final	1 min 25 sec.	790/807
9.	Tokyo 23.10.64	10	Commentary following football final	50 sec.	1320/1330
10.	Tokyo 17.10.64	10	Commentary preceding athletics event	1 min 10 sec.	2977/2991

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